23.0 TRAJECTORY PROCEDURE

23.1 Scope: Trajectory analysis involves the examination of the flight path(s) of projectile(s), and may aid the firearm examiner in determining the approximate physical origins of gunshots and/or approximate location(s) of a shooter(s). Trajectory analysis may also be useful in locating additional physical evidence, including cartridge cases, bullets or bullet fragments, or other ammunition components.

This procedure will describe how a firearm examiner will perform trajectory analyses on vehicles and other types of evidence. This procedure will include the identification, documentation, and reconstruction of bullet flight path(s) based on impact marks. Impact marks may be non-penetrating, penetrating, or perforating. Penetrating impacts are those that enter one surface of an object but do not exit. A non-penetrating impact may create an indention and/or other changes to the surface of the item, but does not break the surface and/or enter the item. Perforating impacts are those that enter and exit an object.

23.2 Precautions/Limitations: The firearm examiner shall pick the appropriate method which will be most effective for the evidence.

23.3 Related Information:

23.3.1 FTIU Chemical and Reagent Manual
23.3.2 FTIU Section 18 – Distance Determination Procedures
23.3.3 FTIU Appendix 8 – Verifications and Casework Review
23.3.4 VCRT 10.22 – Bullet Path Trajectory
23.3.5 FTIU Appendix 4 – Range of Conclusions

23.4 Instruments, Equipment, and Supplies:

23.4.1 Trajectory rods
23.4.2 Angle measuring devices (inclinometer and protractor)
23.4.3 Laser
23.4.4 Tape measure and ruler
23.4.5 Plumb bob and line
23.4.6 Level

23.5 Reagents/Materials:

23.5.1 Sodium Rhodizonate
23.5.2 Buffer Solution

23.6 Hazards/Safety:

23.6.1 It is the responsibility of the firearm examiner to employ appropriate safety and health practices. Bullet impact marks/holes in metal objects and in glass may have sharp edges. Care should be taken to lessen the likelihood of cuts.

23.7 Reference Materials/Controls/Calibration Checks: If utilized, the Sodium Rhodizonate and Buffer solutions will be tested prior to the application of the reagents to the questioned impact marks. The results of this testing shall be recorded in the case notes. See FTIU SOP Section 18 for more information.

23.8 Procedures/Instructions:

23.8.1 Documentation and Initial Examination

- Document and photograph the vehicle or evidence item in its original condition. A Vehicle Worksheet may be used to document vehicles. This documentation should include a narrative description of any observed bullet impact marks and other areas of damage. When using a narrative description for documentation, the examiner should consider using terms such as driver side/passenger side, rather than left side/right side for clarity. A drawing, sketch, or photographs may aid the firearm examiner in locating bullet impact marks and damage.
- The bullet impact marks should be measured on an x, y axis. Z-axis measurements may be made when indicated. Document the location and position to the center of the hole(s).
- The dimensions of bullet impact marks should be measured, and these dimensions may be used to determine the angle of incidence of the impact. However, it is not possible to determine the caliber of the bullet creating the impact marks from the size of the impact or hole.
- The bullet impact marks shall be photographically documented with a scale for reference purposes. Because it may be difficult to differentiate one impact mark from another in close-up photography, it may be useful to identify specific impact marks with a unique letter or number designation prior to photographic documentation.
- Bullet impact marks should be tested for the presence of lead using the Sodium Rhodizonate Test. However, a negative result doesn't indicate the absence of a bullet impact because lead may not always be present in a bullet or may not be transferred onto the target.

23.8.2 Bullet Path Determination Using Trajectory Rods (Multiple Impact Points)

At least two points of reference are generally needed to establish a bullet path. When multiple holes are present, trajectory rods are useful in documenting the bullet path.

- To place trajectory rods, choose the appropriate diameter trajectory rod to put into the hole. It should be a tight fit, but an oversized rod should not be forced into a hole. The sizing cones in the trajectory kits may be used to achieve this fit.
- Carefully align the trajectory rods to enter the secondary or tertiary impact sites. Note: slight deflection may occur when the bullet travels through an object.
- Document the bullet paths with a narrative description, drawing, sketch, photography, or the use of the ScanStation. Documentation using the ScanStation must be performed by authorized personnel.

23.8.3 Determination of Direction of Travel from a Single Impact

A single hole may be used to estimate a bullet path based on the associated shape, relative dimension, depth, and/or physical characteristics present in the substrate.

- For bullet impacts in painted metal, the “boat-wave” effect may be used in determining the direction of travel. As the bullet travels through the sheet metal, it can cause a ripple or crack in the paint layer. These observed “waves” in the paint will resemble the wake coming off the hull of a boat moving through water, in the direction of the bullet travel.
- An additional phenomenon observed when a bullet impacts painted metal is the Pinch Point effect. When a bullet first impacts a painted sheet metal surface, a small area of paint will be crushed into the metal surface. This pinch point will occur at the entry side of the bullet hole or impact site. Additionally, a metal tab may be present at the edge opposite the entry side of the bullet hole or impact site.
- For vehicle windshields (laminated glass), direction of travel can be determined by observing the crater pattern in the glass. Cratering occurs on the opposite side of the glass from the bullet impact. Additional indicators may be present to aid in the determination of the direction of travel, such as bulging or the extrusion of the laminate out one side of the hole. Consult the Microanalysis Unit for determining the Direction of Force on glass. Note: Sodium Rhodizonate testing may still be performed to confirm a bullet impact.
- When non-laminated glass (tempered glass or safety glass) remains intact in a vehicle, it is often possible to determine which of two (or more) shots occurred first by close examination of the fracture pattern of the glass. Glass surrounding the first bullet impact will cause the entire glass surface to fracture. Often the glass shards closest to the impact point will ‘point to’ the impact site. Subsequent bullet impacts to the same glass surface will simply ‘punch out’ fragments of the previously shattered glass. Consult the Microanalysis Unit for Order of Breakage Determination. Note: Sodium Rhodizonate testing may still be performed to confirm a bullet impact.
- When non-laminated glass does not remain intact in a vehicle, it still may be possible to determine the approximate location of the first bullet impact. Glass shards closest to the bullet impact may remain intact, and though the hole is no longer present, these shards ‘point to’ its approximate location. Consult the Microanalysis Unit for Order of Breakage Determination.

23.8.4 Determination of Angle of Incidence

- Using the angle measuring devices, measure the horizontal (azimuth) and vertical angles of the trajectory rod(s). Document these measurements in the case notes. Caution should be exercised in reaching conclusions about trajectories and establishing trajectory angles, taking into account that these are approximations only.

- The angle of incidence (impact angle) of a shot pattern can be calculated using the following trigonometric formula and measurements of the minor and major axis of the shot pattern:

Impact angle = $\sin^{-1}$ (minor axis/major axis).

23.8.5 Recovery of Projectiles and Projectile Fragments

Every attempt should be made to recover the bullets/projectiles/fragments from the termination point of the bullet path(s). Vehicle body molding may be removed to facilitate bullet recovery. Recovered projectiles should be documented as associated with a bullet path, if known.

23.9 Records: The firearm examiner shall document their findings in the form of handwritten notes, computer generated notes, photography, or by utilizing a Vehicle Worksheet. The examiner shall strictly adhere to all note taking procedures as prescribed by laboratory policy.

23.10 Interpretations of Results:

It is not possible to determine the bullet diameter or caliber from the measurement of bullet impact holes or marks.

No angle measurements will be reported. Reporting will be limited to general direction of travel (front to back, driver side to passenger side, etc.).

23.11 Report Writing: Most trajectory report writing can be found in Appendix 4 – Range of Conclusions.

23.12 References:

Association of Firearms and Toolmark Examiners Glossary, 5th Edition, 2007.

Association of Firearms and Toolmark Examiners Training Manual, March 3, 2001.

Association of Firearms and Toolmark Examiners Procedures Manual, July 9, 2001.

Haag, Michael G., and Lucien C. Haag. Shooting Incident Reconstruction, Second Edition. San Diego, CA. Academic Press, 2011.

Hueske, Ed, Introduction to Shooting Incident Reconstruction. CRC Press, 1999.

Hueske, Ed, Recognition and Documentation of Bullet Ricochet Characteristics and Predicting Shot Directionalities, SWAFS Journal, Vol. 25, Issue, July 2003.